

AEGLs, ERPGs, or Rev. 21 TEELs for Chemicals of Concern 2005

Introduction

This document is Revision 21 (DKC-05-0002, September 14, 2005) of a list that provides Protective Action Criteria (PACs) for chemicals of concern. The accompanying tables now include all chemicals for which Final or interim Acute Exposure Guideline Levels (AEGLs), and Emergency Response Planning Guidelines (ERPGs) have been published to date¹, as well as Temporary Emergency Exposure Limits (TEELs). PAC values are provided for 2947 chemicals. **The temporary emergency exposure limits are always subject to change**, being replaced by AEGLs or ERPGs when values are published for new chemicals, and updated when different concentration-limit (e.g., PELs or TLVs) or toxicity data are published.

Table 1 is an alphabetical list of the chemicals substances and their Chemical Abstract Services Registry Numbers (CASRN), as well as some of their physical constants.

Table 2 is an alphabetical list of the AEGLs, ERPGs and TEELs for these chemicals. Values are given in parts per million (ppm) for gases and volatile liquids and in milligrams per cubic meter (mg/m³) for particulate materials (aerosols) and nonvolatile liquids.

Table 3 is a list of TEELs sorted by Chemical Abstract Services Registry Number (CASRN) in the same units (ppm or mg/m³) as Table 2.

Table 4 is an alphabetical list of the TEELs in mass per unit volume (mg/m³) with the ppm to mg/m³ conversion (carried out at 25°C and 760 mmHg) performed before rounding.

PAC values that have been changed since the last revision (Rev 20) are indicated in the last column of Table 2. Chemicals added since publication of "TEELs Rev 20" are indicated.

The DOE SCAPA-approved methodology² was used to obtain concentration-limit derived TEELs. Subsequently, published toxicity parameters from SAX³ and RTECS⁴ were used to derive TEEL-2 and TEEL-3 values for chemicals lacking concentration-limit hierarchy-based values, as documented in a Westinghouse Savannah River Company Technical Report (WSRC-TR-98-00080)⁵ and in "Derivation of Temporary Emergency Exposure Limits (TEELs)"⁶. Several SCAPA-approved improvements to the TEEL-derivation methodology have been made since the above two documents were published (see Appendix 1). Hierarchy-based values are presented as given by the original source, but toxicity-based values are rounded down to powers of 10 of the bases 1, 1.25, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6, or 7.5 (unless the derived value is within 5% of the limit above it, e.g., 290 is rounded to 300). Where applicable, conversion from ppm to mg/m³ is made before rounding.

Further revisions of this document will be issued as warranted.

Hyperlinks to AEGLs published to date, and ERPGs adopted through the 2005 ERPG set, are on SCAPA's home page. <http://www.ora.gov/emi/scapa/teels.htm>. The published TEEL methodology^{5,6} is also available at that same web address. The most recent revision of these tables may be found on DOE EH's Chemical Safety home page in both Adobe Acrobat format (.pdf) and as MS Excel tables http://www.eh.doe.gov/web/chem_safety/ under "Site Map", then "Chemical Management Tools".

Suggestions for improvement of this document, for chemicals to be added to the list, to the format, and other comments, are welcome. All chemicals for which TEELs are derived will be

added to the list. Anyone deriving TEELs for chemicals not on the "TEELs Rev 21" list using the published methodology is asked to send these to craigdk@earthlink.net.

Notes for Tables

The Tables in this document are derived from an Excel Workbook. This has been considerably modified from that described in detail in reference 5, in that nearly all the Excel functions used to automatically calculate TEELs have been replaced by Visual Basic macros. This change reduced the size of the file by a factor of about five, and made the process of adding new chemicals to the list much simpler.

Chemicals whose names are boldface are chemicals for which there are official AEGLs and/or ERPGs. "Added" means that the chemical has been added since "TEELs Rev 20". If a PAC value (AEGL, ERPG, or TEEL) has been changed in "TEELs Rev 21" from previously published values, the affected values are indicated in the last column of Table 2. Changes from previous TEEL Revisions are usually the consequence of the correction or addition of data and rigid adherence to the above automated methodology^{5,6}, any deviation from which is indicated (see Appendix 1). The physicochemical data given in these tables is extracted from various sources, not all of which are in agreement with each other. However, the differences are not usually large enough to be of concern in the conduct of safety analyses. All molecular weights (MW) are given to two decimal places. The primary sources of these data are references 3 (SAX), 4 (ChemBank), 7, and 8.

The method for handling simple asphyxiants has been changed, as detailed in Appendix 2.

Abbreviations used are defined on pages (i) and (ii) of this document. **Hierarchy-based TEEL values** are obtained by strict application of the methodology (described in references 2, 5 and 6) except as noted below or indicated on Table 2.

Information pertinent to the derivation of hierarchy-based TEEL values:

Permissible exposure limits (PEL)⁹ used in earlier revisions of this document were vacated by Court order. Although these vacated values, adopted in 1989 (29 CFR 1910.1000-1910.1200, as of July 1, 1992) are more credible than the 1968 ACGIH TLV values to which the vacated PEL values reverted, they are no longer published in the Federal Register. Most OSHA (PEL), ACGIH (TLV)¹⁰ and NIOSH (REL)⁷ values used are taken from the "Guide to Occupational Exposure Values - 2005"¹¹, compiled by the American Conference of Governmental Industrial Hygienists. This publication also no longer lists vacated PEL values. WEEL¹ values are AIHA Workplace Environmental Exposure Level Guides TWA, STEL or C; "DFG"¹¹ represents concentration limits adopted by the Federal Republic of Germany.

For particulate materials, limits (in mg/m³) are for total dust, even though limits are sometimes also given for the respirable fraction;

PNOS = Particulates Not Otherwise Specified. This TLV-TWA value is for total dust, and the respirable fraction is assumed to be 30% of total concentration;

For substances that are in particulate form, all TEEL values have been reduced to a maximum value of 500 mg/m³. This concentration constitutes an upper bound for a stable cloud of

respirable dust. The reason for this is that the coagulation rate of particles is a function of the square of the **number** concentration. Higher concentrations are unstable;

Values are restricted by the hierarchy-based TEEL for the next higher category, e.g., TEEL-1 is restricted by the TEEL-2 so that **TEEL-0 ≤ TEEL-1 ≤ TEEL-2 ≤ TEEL-3**;

In a few instances, where the IDLH value for a chemical was less than a well-documented TEEL-2 value, the IDLH was not used as the TEEL-3. The IDLH documentation is not as rigorous as that for the 60-minute EEGL or TLV-C values;

For a few chemicals whose "official" ERPG-1 value was odor-based rather than toxicity-based, the TEEL-1 value was adjusted to the PEL-STEEL, TLV-STEEL, or 3 x TLV-TWA value. Where applicable, this is indicated in the last column of Table 2;

Some concentration limit-based TEEL-0 and TEEL-1 values are restricted by a PEL-C or TLV-C value, i.e., **TEEL-0 ≤ TEEL-1 ≤ PEL-C or TLV-C**;

In the absence of other concentration limits or appropriate toxicity data for a chemical, a few values are based on British, Finnish, Russian or other guidelines¹²;

The usual order of use of toxicity data for TEEL-2 and/or TEEL-3 is subordinate to human toxicity data for a particular chemical;

In the absence of both concentration-limit and toxicity based TEEL values, the following default ratios have been used:

$$\text{TEEL-0} = (\text{TEEL-1})/3$$

if there is a TEEL-1;

$$\text{TEEL-1} = (\text{TEEL-0}) \times 3$$

if there is a concentration-limit based TEEL-0, and no PEL-, TLV-, WEEL-, or other STEL;

$$\text{TEEL-1} = (\text{TEEL-2})/7$$

if there is a toxicity-based TEEL-2.

This is based on the mean ratio of existing ERPG-2s to ERPG-1s;

$$\text{TEEL-2} = (\text{TEEL-0}) \times 5$$

if there is a concentration-limit based TEEL-0 and no STEL or C;

$$\text{TEEL-2} = (\text{TEEL-3})/5$$

if there is either a concentration-limit or a toxicity-based TEEL-3.

This is based on the mean ratio of existing ERPG-3s to ERPG-2s;

$$\text{TEEL-3} = (\text{TEEL-2}) \times 5$$

if there is either a concentration-limit or a toxicity-based TEEL-2;

A few values depart from the usual guidelines, and are estimates based on existing concentration limits (at other TEEL values) and/or a comparison with similar chemicals and/or a review of available toxicity data. For example, the TEEL-3 value for 1-Bromo-3-chloro-5,5-dimethylhydantoin is estimated from the toxicity-based TEEL-3 for 3-Bromo-1-chloro-5,5-dimethylhydantoin;

In a few instances, the toxicity-based TEELs were significantly **greater** than the concentration-limit based values and the latter (e.g., some TEEL-2s based on REL-Cs) were ignored. All TEELs other than concentration-limit based values are rounded.

Further Information

Because of its length (nearly 800 pages), "TEELs Rev 21" is not available as a bound hard copy document. Contact Douglas K. Craig for further information, at (386) 304-2524 (Nov. – April), (803) 599-4018 (cell), or by e-mail at craigdk@earthlink.net or the SCAPA web site.

References:

1. The AIHA 2005 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. AIHA Press, Fairfax, Virginia (2005/latest edition).
2. Craig, D.K., J.S. Davis, R. DeVore, D.J. Hansen, A.J. Petrocchi, and T.J. Powell. Alternative Guideline Limits for Chemicals without ERPGs. *Amer. Ind. Hyg. Assoc. J.* 56, 919-925 (1995).
3. Lewis, R.J., Sr.: Sax's Dangerous Properties of Industrial Materials, 11th Edition, John Wiley & Sons, New York, (2005/latest edition. This publication is now available as a CD ROM, now from Wiley Environmental Science).
4. CHEM-BANK™ (June 2005, updated quarterly) Databanks of potentially hazardous chemicals: RTECS[®] – U.S. Department of Health and Human Services (NIOSH) Compact disc Vol. Id:RT36. PP-0018-0073 (SilverPlatter). This CD also includes other data bases, all of which have been scanned for pertinent data if necessary. These include: OHMTADS, TSCA and IRIS – US Environmental Protection Agency; CHRIS – U.S. Department of Transportation (Coast Guard); HSDB – U.S. Library of Medicine; NPG – U.S. National Institute for Occupational Safety and Health (NIOSH), and ERG2004 (Transport Canada, U.S. DOT, Secretariat of Transport/Communications [Mexico]).
5. Craig, D.K. and C. Ray Lux: WSRC-TR-98-00080. Methodology for Deriving Temporary Emergency Exposure Limits (TEELs) (U). Westinghouse Savannah River Company, Aiken, SC (1998).
6. Craig, D.K., J.S. Davis, D.J. Hansen, A.J. Petrocchi, T.J. Powell, and T.E. Tuccinardi, Jr. Derivation of Temporary Emergency Exposure Limits. *J. Appl. Toxicol.* 20, 11-20 (2000).
7. NIOSH Pocket Guide to Chemical Hazards: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control (June 1990). A revised "Guide" was issued in June 1997, and the latest version is included in Ref. 4 above.
8. Lewis, R.J., Sr.: Hawley's Condensed Chemical Dictionary, 14th Ed. John Wiley & Sons, New York, (2001). This publication is available as a CD ROM.

9. Code of Federal Regulations, Title 29 – Labor, Part 1910.1000, Occupational Safety and Health Administration, Air Contaminants, Subpart Z: Toxic and Hazardous Substances. Tables Z-1, Z-2 and Z-3 (July 2005/latest edition).
10. 2005 TLVs^R and BEIs^R Threshold Limit Values for Chemical Substances and Physical Agents: The American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, OH (2005/latest edition)
11. Guide to Occupational Exposure Values – 2005. Compiled by the American Conference of Governmental Industrial Hygienists, Cincinnati, OH (2005/latest edition).
12. Occupational Exposure Limits for Airborne Toxic Substances. Third Edition: Values of Selected Countries prepared from the ILO-CIS Data Base of Exposure Limits, International Labor Office, Geneva (1991).

Appendix 1: Changes to TEEL-derivation methodology approved by SCAPA membership ballot in November 2001

1. Many hierarchy concentration limits (e.g., PELs, TLVs and RELs) for compounds are listed "... as Xy", (e.g., Antimony and compounds, as Sb; Calcium chromate, as Cr; Silver, soluble compounds, as Ag). Intertox changed concentration limits by the ratio of the specific compound to the element for these chemicals, taking into account the compound formulae. This was surely the intent of OSHA, ACGIH, and NIOSH in listing concentration limits this way; it seems logical to incorporate this change in deriving concentration-limit hierarchy-based TEELs. For example, zirconium (Zr) has a molecular weight of 91.22, whereas the molecular weight of zirconium chloride (Zr.Cl₄) is 233.02. The ratio of these molecular weights is 2.55. This is the factor by which the concentration limits (e.g., PEL-TWA = 5 mg/m³) for "Zirconium Compounds, as Zr" must be multiplied for Zr.Cl₄.

Therefore, it was recommended to **"Adjust PEL, TLV, REL, MAK and OEL TWA, STEL and C concentration limits by the compound to element ratio. This simplifies the application of TEELs, and ensures that inappropriate adjustments will not be made. Toxicity-based TEELs (t-Ts) are already compound-specific, so need no adjustment"**.

2. TEEL-2 values are based on LOCs, or PEL, TLV, REL or WEEL ceiling (C) values, or on 5 x TLV-TWA, in order of availability. The ERPG-2 definition given below is frequently interpreted as the threshold concentration for serious or irreversible toxic effects.

Concentration-limit based TEELs (HTs) are frequently much lower than the applicable toxicity data that are available for a chemical would indicate for this threshold. A partial resolution to this problem would be addition of a step to test for large differences between concentration-limit and toxicity-based TEEL-2 and TEEL-3 values.

Therefore, it was recommended to **"Test HTs based on PEL-C (15-minute regulatory limit for workers), TLV-C (well-documented 15-minute per day limit for workers), REL-Cs or 5 x TLV-TWAs against toxicity-based TEEL-2s (t-Ts by all routes of intake).**

If $10 < t-T \text{ to HT ratio} < 100$, then set TEEL-2 = HT x 10

If $t-T \text{ to HT ratio} > 100$, then set TEEL-2 = HT x 100

The usual constraint that TEEL-2 \leq TEEL-3 applies.

TEEL-3s are currently toxicity-based if there is no IDLH".

3. Existing Route Adjustment Factors (RAFs) are estimates, and were based on scientific judgment. It was, for example, assumed that intravenously (iv) injected compounds would be

quantitatively absorbed, so iv administration was assigned an RAF of 1, compared with 0.25 for orally (os) ingested or administered material. This means that it was assumed that four times as much compound needed to be ingested to elicit the same toxic response as the iv-administered compound. This issue was addressed by applying the existing TEEL-derivation methodology to all available acute toxicity data (i.e., for different routes of administration) for 90 chemicals for which ERPGs had been published at the time. To avoid interspecies differences, only rat data were used for this analysis. Rat oral LD₅₀ data were used as the basis for comparison because of the relative abundance of such data. There were sufficient data for three common routes of administration in toxicity studies, namely intraperitoneal (ip), intravenous (iv), and dermal uptake (sk). These analyses showed that current RAFs (RAF-C) for three routes should be revised (RAF-R). Toxic compounds administered by these routes were not as effective relative to oral intake as originally assumed. Therefore, it was recommended to **“Adopt the revised RAFs, which are more soundly based than the existing RAFs”**.

Appendix 2: TEELs for Simple Asphyxiants.

All simple asphyxiants are assigned TEEL values based upon oxygen concentration:
TEEL-0 = 60,000 ppm resulting in an O₂ conc. of about 19.5%, which is OSHA's lower limit for confined space entry in 29 CFR 1915.12 (a)(2).

TEEL-1 = 145,000 ppm resulting in an O₂ conc. of about 18% beginning to produce "decreased ability to work strenuously"

TEEL-2 = 280,000 ppm resulting in an O₂ conc. of about 15% beginning to produce "impaired coordination, perception, and judgment" thereby beginning to deprive a person of the ability to protect himself/herself or perform self-rescue.

TEEL-3 = 500,000 ppm resulting in an O₂ conc. of about 10% beginning to produce "unconsciousness" and then death.

However, should the chemical substance have a lower explosive limit (LEL) that is less than these values, TEELs are limited to the LEL. (These TEEL values will be changed in "TEELs Rev 22" as follows: TEEL-0 = 65,000 ppm, TEEL-1 = 65,000 ppm, TEEL-2 = 230,000 ppm, TEEL-3 = 400,000 ppm)

Appendix 3 Other recent methodology changes.

Incorporation of 60-minute Acute Exposure Guideline Levels (AEGLs) as the first choice, ahead of ERPGs: Sixty-minute final and interim AEGLs have been inserted as the first choice for PACs. These have, therefore, replaced ERPGs at the top of the concentration-limit hierarchy for each hazard level. The title of this document and the tables has been changed to reflect this. The names and CASRNs of chemicals with AEGLs are bolded and in larger font than other chemicals on the list.

Lower Explosive Limits (LELs) were previously not considered. This and future revisions of these tables will flag values as follows:

10% LEL ≤ TEEL < 50% LEL bold green italics

50% LEL ≤ TEEL < 100% LEL bold pink italics underlined

TEEL ≥ LEL bold red italics double underlined.

Source of TEELs column added to Table 4. A brief summary of the data used to derive the PAC values for each listed chemical will be provided in this column. This column appears for the first time in Revision 21 and will be completed as time permits. All chemicals added to the list since the last revision, "TEELs Rev 20", will have this information.

Many chemicals have neither concentration-limit nor toxicity information upon which to base TEELs. Various default strategies have been used to derive TEELs for such chemicals.

Structure Activity Relationships (SAR) have been used to derive TEELs for many of these chemicals, as indicated in the "Source of TEELs" column.

For a few chemicals, TEELs have been based on the values for similar chemicals.

For chemicals that are solids or non-volatile liquids, a default TLV-TWA = 10 mg/m³ for "Particulates Not Otherwise Specified" has been used as the basis of TEELs for those chemicals whose toxicity is dose-dependent only.

For gases and volatile liquids for which the health hazard rating (HHR, or HR in SAX) is available, the following default toxicity information has been used:

HHR = 1: Rat 240 min LC₅₀ = 5000 ppm or rat oral LD₅₀ = 20,000 mg/kg

HHR = 2: Rat 240 min LC₅₀ = 500 ppm or rat oral LD₅₀ = 2000 mg/kg

HHR = 3: Rat 240 min LC₅₀ = 100 ppm or rat oral LD₅₀ = 400 mg/kg

TEELs are dynamic, and change when input data changes (e.g., AEGLs, ERPGs, PEL-TWAs, new acute toxicity). Inconsistencies or errors (often pointed out by users) are corrected as necessary. All changes from previous TEEL list revisions are indicated in the TEEL tables. Adoption of these changes bolsters scientific credibility of TEELs.

Definition of TEELs:

TEELs are intended for use until Acute Exposure Guideline Levels (AEGLs), Emergency Response Planning Guidelines (ERPGs) are adopted for chemicals. With the exception of the recommended averaging time, TEELs 1, 2, and 3 have the same definitions as the equivalent ERPG. These are:

ERPG-1 The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2 The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3 The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Temporary Emergency Exposure Limits (TEELs)

TEEL-0 The threshold concentration below which most people will experience no adverse health effects.

TEEL-1 Same as ERPG-1

TEEL-2 Same as ERPG-2

TEEL-3 Same as ERPG-3

It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak fifteen-minute time-weighted average concentration. It should be emphasized that TEELs are default values, following the published methodology explicitly. The only judgment involved is that exercised in the extraction of data used to calculate the recommended TEELs.

Key to Abbreviations

| | |
|--|--|
| abs – absolute | flash p - flash point |
| ACGIH - American Conference of Governmental Industrial Hygienists | FP, fp - freezing point |
| af - atomic formula | g, gm. - gram |
| AIHA - American Industrial Hygiene Association | glac - glacial |
| alc - alcohol | gran - granular, granules |
| alk - alkaline | hygr - hygroscopic |
| amorph - amorphous | H, hr - hour(s) |
| anhyd -anhydrous | HR - Hazard Rating (SAX) |
| approx - approximately | htd - heated |
| aq -aqueous | htg - heating |
| at, atm - atmosphere | IARC - International Agency for Research on Cancer |
| autoign – auto-ignition | immisc - immiscible |
| aw - atomic weight | incomp - incompatible |
| BEI - ACGIH Biological Exposure Indexes | insol - insoluble |
| BP, bp - boiling point | IU - International Unit |
| b range - boiling range | kg - kilogram (one thousand grams) |
| CASRN - Chemical Abstracts Service Registry Number | L,I - liter |
| cc - cubic centimeter | LEL, lel - lower explosive limit |
| CC - closed cup | liq - liquid |
| CL - ceiling concentration | M - minute(s) |
| COC - Cleveland open cup | m ³ - cubic meter |
| conc - concentration, concentrated | mf - molecular formula |
| compd(s) - compounds | mg - milligram |
| contg - containing | misc - miscible |
| cryst, crys - crystal(s), crystalline | μ, u - micron |
| d - density | mL, ml - milliliter |
| D - day(s) | mm. - millimeter |
| decomp, dec - decomposition | mmHg - pressure in millimeters of mercury |
| deliq - deliquescent | mod - moderately |
| dil - dilute | MP, mp - melting point |
| DOT - U.S. Department of Transportation | mppcf - million particles per cubic foot |
| EPA - U.S. Environmental Protection Agency | MW, mw - molecular weight |
| ERPG - Emergency Response Planning Guidelines of the AIHA | ng - nanogram |
| eth - ether | NIOSH - National Institute for Occupational Safety and Health |
| expls - explodes | nonflam - nonflammable |
| (F) - Fahrenheit | NTP - National Toxicology Program |
| FCC - Food Chemical Codex | OBS - obsolete |
| FDA - U.S. Food and Drug Administration | OC - open cup |
| fibrs - fibers | org - organic |
| flam - flammable | OSHA-Occupational Safety and Health Administration |
| | Pa - Pascals |

Key to Abbreviations (cont.)

PEL - permissible exposure level
 petr - petroleum
 pg - picogram (one trillionth of a gram)
 Pk - peak concentration
 pmole - picomole
 powd - powder
 ppb - parts per billion (v/v)
 pph - parts per hundred (v/v)(percent)
 ppm - parts per million (v/v)
 ppt - parts per trillion (v/v)
 prep - preparation
 press - under pressure
 PROP - properties
 Pwdr - powder
 rhomb - rhombic
 SAX Number - each chemical's identifying
 code as used in SAX3
 SCAPA - Subcommittee on Consequence
 Assessment and Protective Actions
 S, sec - second(s)
 SAR – Structure Activity Relationships
 Si, sit, sitly - slightly
 SG - specific gravity
 sol - soluble
 soln - solution
 solv(s) - solvent(s)
 spont - spontaneously
 STEL - short term exposure limit
 subl - sublimates
 TCC - Tag closed cup
 tech - technical

TEEL - Temporary Emergency Exposure
 Limits
 temp - temperature
 μ, u - micron
 TLV - Threshold Limit Value
 TOC - Tag open cup
 TWA - time weighted average
 U, unk - unknown, unreported
 UEL, uel - upper explosive limit
 μg, ug - microgram
 ULC, ulc -Underwriters Laboratory
 Classification
 USDA - U.S. Department of Agriculture
 vac - vacuum
 vap -vapor
 vap d - vapor density
 Vapor Press, vap press - vapor pressure
 Vol - volume
 visc - viscosity

 vsol - very soluble
 W - week(s)
 Y - year(s)
 % - percent(age)
 > - greater than
 < - less than
 < = - equal to or less than
 > = equal to or greater than
 ° - degrees
 °C - temperature in Celsius (Centigrade)
 (F), °F - temperature in Fahrenheit